Palace Green Library excavations 2013 (PGL13)

Chronology of the burials

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This report synthesises the information on the stratigraphy, chronological constraints and radiocarbon dating of the skeletons excavated at Palace Green Library in 2013 to give the best estimate of their date given all the chronological evidence.

1. *Stratigraphic sequence*

For the purposes of dating the skeletons the relevant stratigraphic information is the sequence of

- a waterlogged deposit (context 508 overlying context 520) which has been radiocarbon dated, followed by
- a sterile sand deposit, into which were cut
- the burial pits (contexts 512, and 514),
- a later pit (context 510), cutting one of the burial pits, which contained clay pipes and glass, and
- the foundations of
    - the southern block of the Bishop's stables, (currently the Library's Learning Centre and part of the Music Department), which was present on this site by 1754 (see report on *History and topography of the site)*.
    - the wall adjoining Windy Gap into which some of the bones have been mortared, with the upper part of the wall probably being 19th century in date.

The arrangement of the human remains in the pits and their co-mingling is indicative of two single occasions of burial, and therefore that the individuals died within a very short space of time. The common features of the two pits suggest that they are also close together in time, and, given the resolution of radiocarbon dating, can be treated as a single event.

2. *Radiocarbon dates*

Initially, four dates were obtained, two on the waterlogged materials (samples 5 and 6) and two on the skeletal remains (samples Sk9 and Sk16A). Although other evidence suggested that these remains should be associated with the prisoners from the Battle of Dunbar, the dates on the skeletons fall slightly before 1650, even when other dating evidence is included (see below). However, these samples were chosen to establish the broad dating of the site and not to obtain results which would resolve chronological questions within a few decades. Therefore, further dating of four samples carefully selected to maximise the precision of the result was undertaken, along with detailed consideration of possible confounding factors (see below).

3. *Evidence of pipe smoking*

Two skeletons (Sk12 and Sk21) showed clear pipe-facets in the teeth which can only arise from a long-term habit of holding a pipe in the teeth. Two others (Sk2 and Sk25) potentially had this wear though the dentition is too incomplete to be certain (see *Skeletal Catalogue*). The evidence of pipe use is strong evidence about the dating.

If the skeletons are prisoners from the Battle of Dunbar then they come from Scotland, otherwise they are likely to be from north-east England. Both possibilities need to be considered.

Tobacco smoking is first documented in Scotland in the first decade of the 17th century and pipes became common in domestic accounts after c.1640 (Gallagher 1987). Tobacco imports were taxed

Context	Sample	Material	$\delta^{13}C$ (‰ PDB)	$\delta^{15}N$ (‰ AIR)	C/N atomic	Lab code	Date	Simple terrestrial calibrated range (95.4% probability, years AD)	% marine
F512	Sk9	Human right femur	-20.5	9.4	3.2	SUERC-54228 (GU34490)	389±30	1440-1530 (68.6%) 1550-1640 (26.8%)	7.0
F514	Sk16A	Human right tibia	-20.7	10.3	3.3	SUERC-54229 (GU34491)	397±30	1430-1530 (74.2%) 1570-1630 (21.2%)	4.7
F520	5	Uncharred *Corylus avellana* nutshell	-26.2			SUERC-54230 (GU34492)	793±30	1190-1280	
F508	6	*Quercus* sp. bark	-30.0			SUERC-54231 (GU34493)	830±30	1160-1270	
F512	Sk12	Human lower left first molar, upper half of root	-20.1	10.8	3.2	SUERC-58783 (GU36756)	358±30	1450-1530 (46.5%) 1540-1660 (48.9%)	11.6
F512	Sk12	Human lower left third molar, upper half of root	-19.6	10.6	3.2	SUERC-58784 (GU36757)	358±28	1450-1530 (47.0%) 1540-1640 (48.4%	17.3
F512	Sk21	Human lower right first molar, upper half of root	-20.3	11.5	3.2	SUERC-58788 (GU36758)	298±30	1490-1660	9.3
F512	Sk21	Human lower right third molar, upper half of root	-20.1	10.3	3.2	SUERC-58789 (GU36759)	292±27	1490-1660	11.6

Table 1: Radiocarbon measurements and simple calibrations assuming terrestrial samples. Calibrated ranges are rounded out to the nearest decade.

from 1612, and a monopoly on them granted in 1616. To make this worthwhile the volume of imports must have been large. Clay pipes became widely available from c.1620, with a monopoly on production granted in 1619 to Lord Kinclevin under which William Banks operated in Edinburgh from 1622 (Gallagher 1987). Pipes were also imported and there is a report in 1635 of seven barrels of Dutch-made pipes being plundered from a shipwreck near Dunbar (Gallagher 1987). Clay pipes are common in archaeological contexts from about 1630, for example a pit at Pittenweem, Fife, dated 1630 to 1640 contained 103 dumped pipe-bowls, and in the area around Biggar, South Lanarkshire, pipes dating to the 1620s have been found but are more common from the 1630s onward (Gallagher 2011).

Tobacco was introduced into England by John Hawkins in 1565 (Morgan 2007), and gradually grew in popularity. Initially, smoking was an activity of the upper classes as tobacco was expensive. Archaeological evidence of clay pipes is known in London from the 1580s onwards (Oswald 1975). In 1612 the first imports from Virginia plantations arrived, and the period 1614 to 1621 saw a twenty-five-fold increase in the import of Virginia tobacco (Rive 1929). Pipemakers spread rapidly across Britain and local production of pipes was found in many small towns from the early 17th century (Oswald 1975).

In the north-east of England there is evidence for pipe manufacture on Tyneside from c.1630 (Edwards 1988:3), and the expenses of the Sheriff for the Northumberland Assizes at Gateshead in 1628 and 1629 include tobacco (Edwards 1988:109). In a collection of clay-pipes from Hartlepool there is a single example of a pipe dated 1580-1610, though the remainder are from after 1660 (Brown and Gallagher 1980). In Yorkshire, White (2004:24) reported 14 known pipes from 1580-1610, but 523 from 1610-1640, indicating the rapid expansion of smoking. The earliest pipes recorded from Durham City are of styles dated c.1610-1640 and c.1620-1640 (Edwards 1993) and until c.1635 London was the only production centre supplying pipes to Durham.

The presence of pipe facets therefore places these individuals certainly after 1565, almost certainly after 1612 and probably after 1620, whichever part of Great Britain they come from.

4. Mathematical modelling

The Bayesian paradigm is adopted here to combine all the chronological evidence (Buck et al. 1996). Bayes Theorem provides a logical framework for the modification of current beliefs in the light of new evidence. Prior dating information, in the form of stratigraphic constraints, known chronological relationships and sample reliability, is incorporated into a mathematical model. This prior information is then combined with the probability distributions that arise from radiocarbon calibration to given posterior probability estimates for the dated samples, but it also allows the estimation of probability ranges for events which have not been directly dated. In practice the calculations for such a model are not suitable for algebraic methods and are conducted in a probabilistic manner on a computer. Using a method known as Markov Chain Monte Carlo, the computer randomly generates a large number of possible scenarios which take account of the radiocarbon dates, the calibration curve and the stratigraphic information, thus deriving probability distributions for the events of interest which take account of all available information. All estimates of calibrated and modelled dates were made using OxCal 4.2 Build 86 (Bronk Ramsey 2009a) and the IntCal13 and Marine13 International Calibration Curves (Reimer et al. 2013). OxCal calculations were performed using OxCal default settings except the use of a resolution of one year and model-dependent increases to the minimum number of iterations to achieve convergence to a stable result. The OxCal code used is given as an appendix.

a. Initial radiocarbon dates

When the first set of dates on the skeletal remains were obtained, they were modelled with a *terminus post quem* of 1612, and varying fractions of marine input in the diet (0%, 10%, 20%). This led to date estimates at 95.4% probability of 1610-1635, 1610-1640, and 1610-1645 respectively (the dates are rounded out to the nearest 5 years). As a marine component to the diet of more than 20% was considered very unlikely on the basis of the $\delta^{13}C$ and $\delta^{15}N$ values, this seemed to show that the date of death was before the Battle of Dunbar. However, the dates are very close to that event, other evidence seemed to point to these being prisoners from the Battle. Further measurements were therefore undertaken to improve the resolution of the dating.

b. Second set of dates

In order to refine the dating, samples were chosen with the clearest possible relationship to the other dating evidence and to maximise the information that the radiocarbon dates can provide. To do this the two individuals with clear evidence of pipe-smoking were sampled in order to maximise confidence that these men died after 1612. A method for maximising the information from radiocarbon dates that is often used with wood samples is wiggle-matching (Bronk Ramsey et al. 2001), where samples separated by a known number of rings are dated and by using the known separation in time of the samples the precision of the calibrated age can be improved by matching the pattern of dates to the calibration curve. To transfer this idea to human remains, tooth roots which form at specific ages in childhood were sampled. The upper half of the root of the first molar forms at 4-6 years of age and the upper half of the root of the third molar forms at 14-16 years of age (AlQahtani et al. 2010), so they are separated by approximately 10 years. Sk12 was aged 19-23 years and Sk 21 was aged 21-25 years (see the *Skeletal Catalogue*). As the individuals involved are relatively young, the time from the third molar formation to death can be estimated fairly precisely thus giving the date of death.

Two sets of models have been used. The first set (A and C models) ignores the uncertainties in the ages of tooth formation and of death, and assumes that there is exactly 10 years between the dates on the two teeth and a further 6 and 8 years to death for Sk12 and Sk21 respectively. The second set (B and D models) treats these gaps as uncertain, expressing that uncertainty as normal distributions of 10±1 years between the teeth and then 6±1 and 8±1 years until death, respectively..

With the models for the second set of dates, the first two dates on Sk9 and Sk16A were included, and allowance was made for the fact that the bone sampled would have formed over a period of time before death. The data of Gosman et al. (2013) were used to calculate approximate turnover times for the midshaft femur of a 17 year old (Sk9) and the midshaft tibia of a 14 year old (Sk16A). From Gosman et al. (2013) Figure 7, the medullary area at the respective ages was taken and the age found at which total cross-sectional area of the bone corresponded to that value. The difference between the two values gives the maximum age of any part of the bone. This value was halved and rounded down to the nearest year to provide average offsets for use in OxCal of 5 years and 4 years respectively. In the B and D models these were assumed to have uncertainties of ±2 years.

c. Marine dietary input

A major difficulty with radiocarbon dating human remains is that humans may consume a mixture of terrestrial foods and marine foods. Because there is a difference in ^{14}C content between the ocean and atmosphere, marine organisms have an apparent radiocarbon age of about 400 years, but with regional variations (Reimer et al. 2009). Thus dates on human bone and dentine require correction for the marine reservoir effect, using knowledge of the local offset from the global marine calibration curve, known as ΔR, and the proportion of marine foods consumed.

A recent estimate of ΔR for the eastern coast of Scotland (and possibly north-eastern England) is -62±53 (Russell et al. 2011), but a more general one for UK waters which is applicable to England is -33±90 (Barrett et al. 2004). These values are very comparable, but in order to account for the range of possible values, Models I and II use ΔR=-62±53 while Model III investigates the effect of using ΔR= -33±90.

The proportion of the carbon in the sample derived from marine sources can be estimated from the ratio of stable carbon isotopes ($\delta^{13}C$ values), using recently established best practice methodology for calibration mixed terrestrial/marine samples procedures (Cook et al. 2015). This involves defining endpoints for human collagen $\delta^{13}C$ values for 100% terrestrial and 100% marine diets, using the fact that human $\delta^{13}C$ values are approximately 1‰ above the $\delta^{13}C$ values of the diet, and allowing a ±10% uncertainty on any computed marine percentage.

The terrestrial diet endpoint varies with climatic and other influences, but can be estimated from herbivore collagen $\delta^{13}C$ values. The equation of van Klinken et al. (2000), which is based on a large dataset of European animal collagen values gives average values of -22.1 to -21.8‰ for Scotland based on the range of July mean temperature for the four mainland stations reported in Müller (1982). This would imply human terrestrial values of -21.1 to -20.8‰. Montgomery et al. (2013) report a large number of human bone and incremental dentine samples from Neolithic Orkney with varying amounts of marine input. The lowest value was -21.1‰, consistent with their ungulate mean of -22.0‰. Terrestrial endpoints for England are generally slightly higher: Roberts et al. (2013) used a value of -20.0‰ for central England, which places four of the six measurements here outside the possible range of values. Likewise the terrestrial animal and bird values from Roman to Late Medieval York (Müldner and Richards 2007) average -21.5‰, suggesting a human 100% terrestrial signal of -20.5‰. As part of this study we have analysed some 16^{th} to 18^{th} century animal bones from Durham, which yielded mean and standard deviations of -21.3±0.6‰ (n=17) for cattle, -21.1±1.0‰ (n=4) for pigs, and -21.5±0.8‰ (n=15) for sheep, giving an average of -21.3‰ across species (see appendix to report on *Isotopic studies of the skeletons*). This small sample has thus yielded values very close to the York fauna, but inconsistent with the skeletons' $\delta^{13}C$ values. A value of -21.1 for 100% terrestrial diet based on Scottish material therefore seems plausible and the uncertainty of ±10% on the calculated % marine values as recommended by Cook et al. (2015) and Hedges (2004) allows for the variability in this value.

For the marine diet endpoint, cod are reported to have $\delta^{13}C$ of -13.4‰ (Russell et al. 2011). The same value was obtained by Montgomery et al. (2013) in Neolithic Orkney based on average values for seal, seabird and cockle in equal proportions. This gives a human collagen endpoint of -12.4‰ which is used here. However, marine fish from York (Müldner and Richards 2007) average -14.5‰. If this value was used the estimated marine contribution to the diet would be increased for a given $\delta^{13}C$ value in human bone and the calibrated dates would be slightly younger. The % marine values would shift by 0.6 to 2.4%, which is negligible compared to the ±10% uncertainty assigned to these values.

The marine contributions to diet have thus been computed using a terrestrial endpoint of -21.1‰ and a marine endpoint of -12.4‰, and are shown in Table 1.

d. Outlier analysis

The initial dates gave slightly different results to the full set, and there is always the possibility of an outlier in radiocarbon dating due to a lack of stratigraphic integrity of the samples or laboratory errors. The models were therefore run a second time (C and D models) with outlier analysis (Bronk Ramsey 2009b) to test for samples which do not fit with the rest of the information. OxCal's General Outlier model was used with default settings and a prior probability of being an outlier of 5% for all dates.

5. Results and discussion

The B models proved to be computationally unstable when the *terminus ante quem* of 1754 was used, failing to converge on a stable estimate. As the radiocarbon dates and the results of other models showed clearly that there could be no probability of dates in the 18^{th} century, an earlier *terminus ante quem* was used to make each model computationally stable without affecting the results, and these are shown in Table 2.

The results of modelling are summarised in Table 2, and OxCal multiplots of all parameters in each model are presented in the Appendix. Ranges are presented to the nearest year but because of rounding and interpolation of values a variation of one year either way may occur on repeated calculations of the same model. Outlier analysis showed no significant increase from the starting

Model	TPQ	TAQ	ΔR	Gaps	Date of death (95.4% probability)	Outlier probabilities
I A	1612	1754	-62±53	Fixed	1627-1656	—
I B	1612	1740*	-62±53	Uncertain	1628-1654	—
I C	1612	1754	-62±53	Fixed	1616-1618 (0.9%) 1626-1657 (94.5%)	3-6%
I D	1612	1754	-62±53	Uncertain	1612-1619 (1.9%) 1625-1658 (93.5%)	3-7%
II A	1620	1754	-62±53	Fixed	1628-1654	—
II B	1620	1700*	-62±53	Uncertain	1628-1655	—
II C	1620	1754	-62±53	Fixed	1627-1656	3-6%
II D	1620	1754	-62±53	Uncertain	1627-1656	3-6%
III A	1612	1754	-33±90	Fixed	1627-1658	—
III B	1612	1700*	-33±90	Uncertain	1630-1656	—
III C	1612	1754	-33±90	Fixed	1626-1660	3-6%
III D	1612	1754	-33±90	Uncertain	1626-1662	3-7%

Table 2: Results for mathematical models of the date of death, with sensitivity testing of possible scenarios. Models which failed to compute with TAQ of 1754 are indicated with an asterisk against the alternative value used.

value of 5% for any sample and thus provided no evidence that any of the measurements is an outlier or fails to fit within the model. The results of the outlier models C and D are only marginally different to the models without outlier analysis. Adding uncertainty to the gaps in the chronological sequence (models B and D) consistently shifts the results a year or two later but makes no substantial difference. The choice of 1612 (model I) or 1620 (model II) as a *terminus post quem* also makes little difference. It is conventional to round the ranges outward to avoid a spurious appearance of precision (Millard 2014), and as the calibration curve data is presented at 5 year intervals, the minimum appropriate rounding is outwards to the next 5 years. On that basis the results for the date of death from the 12 models presented in Table 2 may be encompassed within the range 1625-1660, with a very small probability of 1610-1620.

6. Conclusion

Considering all the possible influences on the radiocarbon dates and the other constraints on dating, the chronological evidence suggests the burials took place between 1625 and 1660 and is consistent with the most likely historical context for these burials: the imprisonment of Scots soldiers from the Battle of Dunbar in 1650.

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8. References

AlQahtani SJ, Hector MP, Liversidge HM. 2010. Brief communication: The London atlas of human tooth development and eruption. American Journal of Physical Anthropology 142:481-490.

Barrett JH, Locker AM, Roberts CM. 2004. The origins of intensive marine fishing in medieval Europe: the English evidence. Proceedings of the Royal Society of London Series B-Biological Sciences 271:2417-2421.

Bronk Ramsey C. 2009a. Bayesian analysis of radiocarbon dates. Radiocarbon 51:337-360.

Bronk Ramsey C. 2009b. Dealing with outliers and offsets in radiocarbon dating. Radiocarbon 51:1023-1045.

Bronk Ramsey C, van der Plicht J, Weninger B. 2001. 'Wiggle matching' radiocarbon dates. Radiocarbon 43:381-389.

Brown MM, Gallagher DB. 1980. A study of the clay tobacco pipes from Hartlepool. In: Davey P, editor. The archaeology of the clay tobacco pipe 3 Britain: the north and west. Oxford: British Archaeological Reports. p 19-28.

Buck CE, Litton C, Cavanagh W. 1996. Bayesian approach to interpreting archaeological data. Chichester: Wiley.

Cook GT, Ascough PL, Bonsall C, Hamilton WD, Russell N, Sayle KL, Bownes JM, Scott EM. 2015. Best Practice Methodology for 14C Calibration of Marine and Mixed Terrestrial/Marine Samples. Quaternary Geochronology in press.

Edwards L. 1988. The archaeology of the clay tobacco pipe. 11, Seventeenth and eighteenth century Tyneside tobacco pipe makers and tobacconists. Oxford: British Archaeological Reports.

Edwards LJ. 1993. Clay tobacco pipes from Durham City: a brief summary. Durham Archaeological Journal 9:98-100.

Gallagher DB. 1987. Edinburgh pipemakers in the seventeenth century: the documentary evidence. In: Davey P, editor. The archaeology of the clay tobacco pipe X Scotland. Oxford: BAR British Series. p 3-34.

Gallagher G. 2011. Study of the tobacco pipes from Biggar Archaeology Group's projects 1981-2010. Biggar Archaeology Group, http://www.biggararchaeology.org.uk/pdf_reports/BAG_CLAYPIPES_REPORT2010_f.pdf.

Gosman JH, Hubbell ZR, Shaw CN, Ryan TM. 2013. Development of cortical bone geometry in the human femoral and tibial diaphysis. The Anatomical Record 296:774-787.

Hedges REM. 2004. Isotopes and red herrings: comments on Milner et al. and Liden et al. Antiquity 78:34-37.

Millard AR. 2014. Conventions for reporting radiocarbon determinations. Radiocarbon 52:555-559 DOI: 510.2458/2456.17455.

Montgomery J, Beaumont J, Jay M, Keefe K, Gledhill AR, Cook GT, Dockrill SJ, Melton ND. 2013. Strategic and sporadic marine consumption at the onset of the Neolithic: increasing temporal resolution in the isotope evidence Antiquity 87:1060-1072.

Morgan B. 2007. Hawkins, Sir John (1532–1595). Oxford Dictionary of National Biography. Oxford: Oxford University Press, http://www.oxforddnb.com/view/article/12672.

Müldner G, Richards MP. 2007. Stable isotope evidence for 1500 years of human diet at the city of York, UK. American Journal of Physical Anthropology 133:682-697.

Müller MJ. 1982. Selected climatic data for a global set of standard stations for vegetation science. The Hague: Dr W Junk.

Oswald A. 1975. Clay pipes for the archaeologist. Oxford: British Archaeological Reports.

Reimer PJ, Baillie MGL, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE, Burr GS, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg AG, Hughen KA, Kaiser KF, Kromer B, McCormac FG, Manning SW, Reimer RW, Richards DA, Southon JR, Talamo S, Turney CSM, van der Plicht J, Weyhenmeyer CE. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. Radiocarbon 51:1111-1150.

Reimer PJ, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE, Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Haflidason H, Hajdas I, Hatté C, Heaton TJ, Hoffmann DL, Hogg AG, Hughen KA, Kaiser KF, Kromer B, Manning SW, Niu M, Reimer RW, Richards DA, Scott EM, Southon JR, Staff RA, Turney CSM, van der Plicht J. 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP. Radiocarbon 55:1869-1887.

Rive A. 1929. A Brief History of the Regulation and Taxation of Tobacco in England. The William and Mary Quarterly 9:1-12.

Roberts CA, Millard AR, Nowell GM, Gröcke DR, Macpherson CG, Pearson DG, Evans DH. 2013. Isotopic tracing of the impact of mobility on infectious disease: The origin of people with treponematosis buried in Hull, England, in the late medieval period. American Journal of Physical Anthropology 150:273-285.

Russell N, Cook GT, Ascough P, Barrett JH, Dugmore A. 2011. Species specific marine radiocarbon reservoir effect: a comparison of ΔR values between Patella vulgata (limpet) shell carbonate and Gadus morhua (Atlantic cod) bone collagen. Journal of Archaeological Science 38:1008-1015.

van Klinken G-J, Richards MP, Hedges REM. 2000. An overview of causes for stable isotopic variations in past European human populations: environmental, ecophysiological and cultural effects. In: Ambrose SH, Katzenberg MA, editors. Biogeochemical approaches to paleodietary analysis. New York: Kluwer Academic/Plenum. p 39-63.

White SD. 2004. The archaeology of the clay tobacco pipe. 18. The dynamics of regionalisation and trade: Yorkshire clay tobacco pipes, c1600-1800. Oxford: Archaeopress.